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[Title of the Invention] Active Matrix Liquid Crystal Display Device

[Claims]

[Claim 1] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, and a liquid crystal layer sandwiched between said first substrate and said second substrate, said device comprising:

a plurality of pixel electrodes arranged in a matrix on said first substrate;

a data line disposed on said first substrate correspondingly to a position of a gap between adjacent two of the pixel electrodes, for supplying data signals to said switching element; and

a black matrix formed on said first substrate in association with said data line, for blocking light passing in a predetermined viewing angle range through a light leakage region created in said liquid crystal layer depending on a potential difference between adjacent two of the pixel electrodes.

[Claim 2] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, and a liquid crystal layer sandwiched between said first substrate and said second substrate, said device comprising:

a data line disposed on said first substrate for supplying data signals to said switching element;

an overcoat layer disposed on said first substrate in covering relation to said data line and said first substrate;

a plurality of pixel electrodes arranged in a matrix on said overcoat layer; and

a black matrix disposed on said data line in contact with a surface on said first substrate side of said overcoat layer;

wherein said data line is disposed at a gap between adjacent two of the pixel electrodes, and

said black matrix is formed to block light passing in a predetermined

viewing angle range through a light leakage region created in said liquid crystal layer depending on a potential difference between adjacent two of the pixel electrodes.

[Claim 3] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, a liquid crystal layer sandwiched between said first substrate and said second substrate, a data line disposed on said first substrate, for supplying data signals to said switching element, an overcoat layer disposed on said first substrate in covering relation to said data lines and said first substrate, and a plurality of pixel electrodes arranged in a matrix on said overcoat layer, said data line being disposed correspondingly to a position of a gap between adjacent two of said pixel electrodes, said device comprising:

a black matrix disposed on said data lines;

wherein said black matrix having a portion overlapping said pixel electrodes, and said portion having a width W satisfying:

$W \geq d_{LC}/2 + d_{OC} \cdot \tan\theta$, for a case in which said active matrix liquid crystal display device is driven by a dot inversion driving process, and

$W \geq d_{LC}/4 + d_{OC} \cdot \tan\theta$, for a case in which said active matrix liquid crystal display device is driven by a gate line inversion driving process, where d_{LC} represents a thickness of said liquid crystal layer, d_{OC} represents a thickness of said overcoat layer on said black matrix, and 2θ represents a given viewing angle 2θ.

[Claim 4] An active matrix liquid crystal display device according to claim 3, wherein the thickness d_{OC} of said overcoat layer on said black matrix is at most 1 μm and said overcoat layer planarizes steps of said black matrix to at most 0.5 μm.

[Claim 5] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, and a liquid crystal layer sandwiched between said first substrate and said second substrate, said device comprising:

a data line disposed on said first substrate, for supplying data signals to said switching element;

an overcoat layer disposed on said first substrate in covering relation to said data line and said first substrate;

a plurality of pixel electrodes arranged in a matrix on said overcoat layer; and

a black matrix disposed on said data lines;

wherein said data line is disposed correspondingly to a position of a gap between adjacent two of the pixel electrodes, and; said black matrix is disposed in a position above said data lines, and

said black matrix is arranged to block light passing in a predetermined viewing angle range through a light leakage region created in said liquid crystal layer depending on a potential difference between adjacent two of the pixel electrodes.

[Claim 6] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, a liquid crystal layer sandwiched between said first substrate and said second substrate, a data line disposed on said first substrate, for supplying data signals to said switching element, an overcoat layer disposed on said first substrate in covering relation to said data lines and said first substrate, and a plurality of pixel electrodes arranged in a matrix on said overcoat layer, said data line being disposed correspondingly to a position of a gap between adjacent two of said pixel electrodes, said device comprising:

a black matrix disposed on said overcoat layer at a position above said data line;

wherein said pixel electrodes having a portion extending over said black matrix, and said portion having a width W satisfying:

$W \geq d_{LC}/2$, for a case in which said active matrix liquid crystal display device is driven by a dot inversion driving process, and

$W \geq d_{LC}/4$, for a case in which said active matrix liquid crystal display device is driven by a gate line inversion driving process,

where d_{LC} represents a thickness of said liquid crystal layer, and 2θ represents a given viewing angle.

[Claim 7] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, a liquid crystal layer sandwiched between said first substrate and said second substrate, a data line disposed on said first substrate, for supplying data signals to said switching element, an overcoat layer disposed on said first substrate in covering relation to said data lines and said first substrate, and a plurality of pixel electrodes arranged in a matrix on said overcoat layer, said data line being disposed correspondingly to a position of a gap between adjacent two of said pixel electrodes, said device comprising:

a black matrix disposed on said overcoat layer at a position above said data line;

wherein said black matrix having a portion extending over said pixel electrodes, and said portion having a width W satisfying:

$W \geq d_{LC}/2$, for a case in which said active matrix liquid crystal display device is driven by a dot inversion driving process, and

$W \geq d_{LC}/4$, for a case in which said active matrix liquid crystal display device is driven by a gate line inversion driving process,

where d_{LC} represents a thickness of said liquid crystal layer, and 2θ represents a given viewing angle.

[Claim 8] An active matrix liquid crystal display device according to any one of claim 1 to 8, wherein a color layer constituting a color filter is disposed on said first substrate.

[Claim 9] An active matrix liquid crystal display device according to any one of claims 1 to 8, wherein the black matrix is made of an electrically insulating material.

[Claim 10] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, and a liquid crystal layer sandwiched between said first substrate and said second substrate, said device

comprising:

a data line disposed on said first substrate, for supplying data signals to said switching element;

a color layer, for constituting a color filter, disposed in at least a region of said first substrate which is free of said data line;

a plurality of pixel electrodes disposed on said color layer and arranged in a matrix; and

a black matrix of an electrically insulating material disposed on said data line;

wherein said data line is disposed correspondingly to a position of a gap between adjacent two of the pixel electrodes, and

said black matrix is formed to block light passing in a predetermined viewing angle range through a light leakage region created in said liquid crystal layer depending on a potential difference between adjacent two of the pixel electrodes.

[Claim 11] An active matrix liquid crystal display device which comprises a first substrate on which a switching element is formed, a second substrate disposed in opposing relation to said first substrate, and a liquid crystal layer sandwiched between said first substrate and said second substrate, said device comprising:

a data line disposed on said first substrate, for supplying data signals to said switching element;

a color layer, for constituting a color filter, disposed in at least a region of said first substrate which is free of said data line;

a plurality of pixel electrodes disposed on said color layer and arranged in a matrix; and

a black matrix of an electrically insulating material disposed on said data line;

wherein said data line is disposed correspondingly to a position of a gap between adjacent two of the pixel electrodes, and

said pixel electrodes having a portion extending over said black matrix, and said portion having a width W satisfying:

$W \geq d_{LC}/2$, for a case in which said active matrix liquid crystal display device is driven by a dot inversion driving process, and

$W \geq d_{LC}/4$, for a case in which said active matrix liquid crystal display device is driven by a gate line inversion driving process,

where d_{LC} represents a thickness of said liquid crystal layer, and 2θ represents a given viewing angle.

[Detailed Explanation of the Invention]

[0001]

[Technical Field to which the Invention Pertains]

The present invention relates to an active matrix liquid crystal display device.

[0002]

[Prior Arts]

Heretofore, active matrix liquid crystal display devices capable of displaying color images have been of a structure including a TFT (Thin-Film Transistor) substrate with TFTs and pixel electrodes disposed thereon in association with respective pixels, an opposing substrate with color filters and a common electrode disposed thereon, the opposing substrate disposed in opposing relation to the TFT substrate, and a liquid crystal layer sealed between the TFT substrate and the opposing substrate. In this structure, there are requirements on fabrication that the color filters and the pixel electrodes need to be positioned accurately in alignment with each other and that, in order to prevent an unwanted leakage of light, a black matrix (light shielding layer) is required to be positioned between the color filters for the respective pixels. In view of these requirements, it has been proposed to fabricate color filters on a TFT substrate. With color filters fabricated on a TFT substrate, an opposing substrate can be constructed of a transparent substrate and a transparent common electrode fabricated uniformly over the transparent substrate. Therefore, the manufacturing process is simplified, and it is relatively easy to achieve precise alignment between the opposing substrate and the TFT substrate. In addition, various interconnections on the TFT substrate can be used as a light shielding layer.

[0003]

FIG. 5 shows in schematic cross-sectional view of a conventional active matrix liquid crystal display device with color filters mounted on a TFT substrate side.

[0004]

TFT substrate 10 has a structure a plurality of patterned data lines (also referred to as video signal lines or drain lines and source lines) 12 extending parallel to each other are disposed on one major surface of transparent glass substrate 11, color layers 13 of color filters and transparent overcoat layer 14 are successively deposited on the major surface of transparent glass substrate 11, and transparent pixel electrodes 15 are disposed on the surface of overcoat layer 14 in association with the respective pixels. Data lines 12 are covered with color layers 13, and extend in a direction normal to the sheet of FIG. 5. On the other hand, opposing substrate 20 has a construction in which a transparent uniform common electrode 22 is disposed on one major surface of glass substrate 21. The liquid crystal display device has a structure in which TFT substrate 10 and opposing substrate 20 are spaced a given distance from each other with pixel electrodes 15 and common electrode 22 confronting each other, and liquid crystal layer 30 is sealed between TFT substrate 10 and opposing substrate 20. Each of data lines 12 is made of an opaque conductive material and serves to block gaps between two adjacent pixels against the entry of light. As well known to those skilled in the art, TFT substrate 10 also supports gate lines (also referred as scanning lines) and TFTs associated with the respective pixels.

[0005]

FIG. 6 is an equivalent circuit diagram of such an active matrix liquid crystal display device.

[0006]

Pixel electrodes 15 and TFTs 41 which are associated with the respective pixels are arranged in a matrix form on TFT substrate 10. TFTs 41, which operate as switching elements, have gates connected to gate lines 42, drains connected to data lines 12, and sources connected to pixel electrodes

15. However, the sources of TFTs 41 may be connected to data lines 12, and the drains thereof to pixel electrodes 15. Common electrode 22 is grounded, and a liquid crystal layer sandwiched between common electrode 22 and one pixel electrode 15 serves as one pixel portion 40. On TFT substrate 10, gate lines 42 extend parallel to each other and perpendicularly to data lines 12. Pixel capacitors 43 are equivalently connected parallel to the respective pixel portions 40. Data lines 12 and gate lines 42 are driven respectively by drivers 44 and drivers 45.

[0007]

[Problem to be Solved by the Invention]

It has been pointed out that the above conventional active matrix liquid crystal display device with the color filters on the TFT substrate has a smaller viewing angle than the active matrix liquid crystal display device with the color filters on the opposing substrate, even if it is provided with a phase difference compensation plate. Table 1 shows measured viewing angles in vertical and horizontal directions of active matrix liquid crystal display devices with color filters on TFT substrates and an active matrix liquid crystal display device with color filters on an opposing substrate. The values set forth in Table 1 were obtained with phase difference compensation plates used.

[0008]

[Table 1]

Type	9.4" UXGA	12.1" SVGA	12.1" SVGA
Pixel pitch	120 μm	300 μm	300 μm
Color filter position	TFT substrate	TFT substrate	Opposing substrate
Viewing angle (Vertical)	90 degrees	92 degrees	90 degrees
Viewing angle (Horizontal)	90 degrees	105 degrees	110 degrees

[0009]

The viewing angle referred to above is an angle in which the ratio of contrast between white and black display images is 10 % or higher. As can be seen from Table 1, the vertical viewing angle remains substantially the same

irrespective of whether the color filters are disposed on the opposing substrate or the TFT substrate. However, the horizontal viewing angle is much smaller with the color filters disposed on the TFT substrate than with the color filters disposed on the opposing substrate. This tendency manifests itself if the pixels are smaller.

[0010]

The reason why such a phenomenon occurs will be described with reference to FIG. 5.

[0011]

It is assumed that the conventional active matrix liquid crystal display device shown in FIG. 5 is used in a normally white mode. If pixels disposed one on each side of data line 12 displays a black image, then when the liquid crystal display device is driven by a dot inversion driving process, since a voltage of +5 V is applied to one of the pixel electrodes and a voltage of -5 V is applied to the other pixel electrode, a strong lateral electric field is generated in a region above data line 12 of liquid crystal layer 30, causing directors (liquid crystal molecules) 31 to fall thereby to substantially display a white image in that region. Specifically, as indicated by A in FIG. 5, a white image is displayed in the region of the gap between pixel electrodes 15 and a region slightly extending from the gap into the pixel electrodes. These regions are combined as a region where light leaks. In the other region, directors 31 are erected parallel to the direction from pixel electrodes 15 to common electrode 22, and a black image is displayed. When the white image region is viewed from the front of the active matrix liquid crystal display device, it is visually recognized as a black region because light is blocked by data line 12. When the white image region is obliquely viewed, as indicated by the arrow B, light is not blocked by data line 12, and liquid crystal layer 30 is affected by light that passes only through light leakage region A. While the region should be the black region, since there is light passing through liquid crystal layer 30 as indicated by the arrow B, the contrast in the black region is lowered (so-called whitening in black), resulting in a reduction in the intensity of black in the black region.

[0012]

As it is obvious from the above description, if the liquid crystal display device is a highly fine display panel with small pixel pitches, then because the ratio of light leakage regions to ordinary pixel regions (i.e., normal regions: regions where liquid crystal molecules are vertically oriented to display a black image as described above) tends to be larger than a display panel with greater pixel pitches, the contrast in the black region as obliquely viewed is reduced, resulting in a smaller viewing angle.

[0013]

The similar phenomenon can occur with respect to the gate lines. However, inasmuch as a relatively large voltage is applied to the gate lines at all times unlike the data lines, and pixel electrodes are of a rectangular shape that is elongate parallel to the data lines in a color active matrix liquid crystal display device, the above phenomenon with respect to the gate lines is not so noticeable as with the data lines, and does not lead to a substantial reduction in the viewing angle and visual perception.

[0014]

In order to prevent the contrast from being lowered and also to prevent the viewing angle from being reduced, Japanese laid-open patent publication No. 10-104664 (JP, 10104664, A), for example, discloses an arrangement in which data lines have an increased width and overlap pixel electrodes with an overcoat layer interposed therebetween. The disclosed arrangement, however, is disadvantageous in that because the data lines need to be extremely large in width in order to achieve a desired viewing angle, the aperture ratio is lowered, and the layout of TFTs and auxiliary capacitors is limited.

[0015]

It is therefore an object of the present invention to provide an active matrix liquid crystal display device which is capable of providing a wide viewing angle without the need for widened data lines even if color filters are disposed on a TFT substrate.

[0016]

[Means for Solving the Problem]

The active matrix liquid crystal display device according to the present

invention is an active matrix liquid crystal display device which comprises a first substrate (TFT substrate) on which a switching element is formed, a second substrate (opposing substrate) disposed in opposing relation to the first substrate, and a liquid crystal layer sandwiched between the first substrate and the second substrate, the device comprising: a plurality of pixel electrodes arranged in a matrix on the first substrate; a data line disposed on the first substrate correspondingly to a position of a gap between adjacent two of the pixel electrodes, for supplying data signals to the switching element; and a black matrix formed on the first substrate in association with the data line, for blocking light passing in a predetermined viewing angle range through a light leakage region created in the liquid crystal layer depending on a potential difference between adjacent two of the pixel electrodes. The black matrix is provided to block light that passes through a light leakage region created in gaps between the pixel electrodes for thereby increasing the contrast as viewed in an oblique direction to increase a viewing angle. Therefore, dimensions of the black matrix are determined depending on a desired viewing angle and the extent of the light leakage region. The present invention also provides a simple mathematical expressions for determining the width of the black matrix (the extent of the black matrix in a direction perpendicular to the direction in which the data lines extend).

[0017]

In the active matrix liquid crystal display device according to the present invention, color layers constituting color filters are typically disposed on the first substrate. In the active matrix liquid crystal display device according to the present invention, an overcoat layer may be disposed on the first substrate. With the overcoat layer disposed on the first substrate, the black matrix may be disposed below the overcoat layer, i.e., first substrate side, or above the overcoat layer, i.e., the liquid crystal layer side.

[0018]

[Modes for Carrying out the Invention]

Next, the preferred embodiments of the present invention will be described.

[0019]

FIG. 1 is a cross-sectional view showing a constitution of an active matrix liquid crystal display device according to a first embodiment of the present invention. This active matrix liquid crystal display device is similar to the conventional liquid crystal display device shown in FIG. 5 in that color filters (color layers 13) are disposed on TFT substrate 10, but differs therefrom in that black matrix 16 serving as a light shielding layer for blocking light applied in an oblique direction is also disposed on TFT substrate 10. The liquid crystal display device shown in FIG. 1 will be described in detail.

[0020]

In TFT substrate 10, a plurality of patterned data lines 12 extending parallel to each other are patterned and disposed on one major surface of transparent glass substrate 11, and color layers 13 constituting color filters are disposed in regions of the major surface of glass substrate 11 which are not covered with data lines 12. Data lines 12 are made of an opaque conductive material, and extend in a direction normal to the sheet of FIG. 1. Color layers 13 have portions extending from edges of data lines 12 onto upper surfaces of data lines 12.

[0021]

Black matrix 16 is disposed over data line 12 and extends in the same direction as data line 12. Black matrix 16 has a lower surface held against the upper surface of data line 12. Black matrix 12 extends laterally over the portions of color layers 13 that extend onto data line 12, and extends further toward centers of color layers 13 beyond portions thereof which correspond to the edges of data line 12. The width or distance by which black matrix 16 extends over the portions of color layers 13 will be described later on. Black matrix 16 is made of a material having a light shielding capability. In the present embodiment, black matrix 16 may be electrically conductive. However, if black matrix 16 is electrically conductive, then it makes data lines 12 electrically larger in width, possibly tending to adversely affect the electric characteristics of the liquid crystal display device. Therefore, black matrix 16 should preferably be made of an electrically insulating material such as a resin

with a fine powder of carbon black dispersed therein, for example.

[0022]

Transparent overcoat layer 14 is disposed in smoothly covering relation to the upper surface of color layers 13 and the upper surface of black matrix 16. Transparent pixel electrodes 15 associated with respective pixels are disposed on the upper surface of overcoat layer 14. Pixel electrodes 15 are arranged in a matrix form on overcoat layer 14, and made of ITO (indium-tin oxide), for example. Each of data lines 12 is disposed in alignment with the gap between two adjacent pixel electrodes 15.

[0023]

TFT substrate 10 also supports thereon gate lines, not shown, and TFTs, not shown, associated with the respective pixels. The TFTs are supplied with data signals from data lines 12. The active matrix liquid crystal display device also has a pair of polarizers, not shown, and a phase difference compensation plate, not shown.

[0024]

Opposing substrate 20, which is identical to the opposing substrate shown in FIG. 1, has transparent glass substrate 21 and transparent common electrode 22 of ITO, for example. In this liquid crystal display device, TFT substrate 10 and opposing substrate 20 are spaced a given distance from each other with pixel electrodes 15 and common electrode 22 confronting each other. A liquid crystal layer 30 is sealed between TFT substrate 10 and opposing substrate 20.

[0025]

Next, the transverse dimension (horizontal direction in FIG. 1) of black matrix 16 will be described below. Black matrix 16 blocks light passing through light leakage region A in the gap between pixel electrodes 15, thereby increasing the contrast as viewed in an oblique direction and hence increasing a viewing angle. Light applied in an oblique direction and passing through a normal region other than light leakage region A is considerably reduced when it passes through the normal region when a voltage is applied to the pixel electrodes 15 in a normally white mode to display a black image. Therefore,

such light is not considered as having a significant effect on a reduction in the contrast. The width of black matrix 16 may thus be determined depending on how large an angular range of light applied in an oblique direction and passing through only the light leakage region may be. The width of black matrix 16 may be determined such that a light path (the light path indicated by arrow C in FIG. 1) which is inclined to the normal to glass substrate 21 by θ and passes through an end of light leakage region A near overcoat layer 14 touches an end of black matrix 16, with a desired viewing angle being represented by 2θ. If the width of black matrix 16 is thus determined, then light that passes through light leakage region A without being blocked by data line 12 is blocked by black matrix 16, as indicated by the arrow D in FIG. 1.

[0026]

Specifically, the position of the light leakage region is determined based on the thickness d_{LC} of liquid crystal layer 30, the thickness d_{OC} of overcoat layer 14, electrical properties of liquid crystal layer 30, spaced intervals and layout of pixel electrodes 15, and optical properties such as refractive indexes of the various layers, and the width of black matrix 16 may be determined to obtain a desired viewing angle.

[0027]

The width of black matrix 16 can be determined in this manner according to a known simulation technique. However, since there are many factors involved in determining the width of black matrix 16, a large amount of calculations is required to determine an optimum width for black matrix 16. The inventor of the present invention has conducted experiments and found a simpler process of determining the dimension of black matrix 16. This simpler process of determining the dimension of black matrix 16 will be described below.

[0028]

With a liquid crystal display device that is presently manufactured, each of the thickness d_{LC} of liquid crystal layer 30, the gap between adjacent pixel electrodes 15, and the thickness d_{OC} of overcoat layer 14 on black matrix 16 is considered to be in the range from several micrometers to ten and several micrometers. When such a liquid crystal display device is used in a normally

white mode and a black image is displayed on each of adjacent pixels positioned across data line 12 (black matrix 16), light leakage region A is created by a lateral electric field produced between pixel electrodes 15 (or a reduction in a vertical electric field in a region between pixel electrodes 15). Light leakage region A is not limited to a region corresponding to the gap between pixel electrodes 15, but extends somewhat from the edges of pixel electrodes 15 toward the centers of pixel electrodes 15. In the arrangement shown in FIG. 1, since black matrix 16 is disposed below pixel electrodes 15 with overcoat layer 14 interposed therebetween, the width of black matrix 16 needs to be larger than the gap between pixel electrodes 15. Black matrix 16 overlaps pixel electrodes 15 by distances or widths W.

[0029]

The lateral electric field in liquid crystal layer 30 described above obviously varies depending on whether a voltage is applied to each pixel electrode 15 according to a dot inversion driving process or a gate line inversion driving process. The inventor has studied the above presently manufactured liquid crystal display device in view of the above different drive processes, and has found that, with the viewing angle being represented by 2θ, the width W of the overlapping regions may be determined to meet the following condition:

$W \geq d_{LC}/2 + d_{OC} \cdot \tan\theta$ (for a case of the dot inversion driving process); and

$W \geq d_{LC}/4 + d_{OC} \cdot \tan\theta$ (for a case of the gate line inversion driving process),

where the viewing angle referred to above is an angle in which the ratio of contrast between white and black display images is 10 % or higher. This definition will also be used hereinbelow. Of course, it is preferable to reduce the width W while satisfying the above expressions because an unduly increase in the width W results in a reduction in the aperture ratio.

[0030]

Table 2 given below shows the relationship between the viewing angle 2θ in which the ratio of contrast between white and black display images is 10 % or higher and the width W of overlapping regions of liquid crystal display

panels of 9.4" UXGA (the pixel pitch of 120 μm) with phase difference compensation plates, where the thickness d_{LC} of liquid crystal layer 30 is 4.5 μm, the gap between adjacent pixel electrodes 15 is 6 μm, and the thickness d_{OC} of overcoat layer 14 on black matrix 16 ranges from 0.5 to 30 μm, and a voltage is applied according to the dot inversion driving process. It can be understood from Table 2 that good display characteristics and viewing angle characteristics can be obtained by determining the width W to satisfy the above formulae.

[0031]

A review of Table 2 indicates that it is necessary to set the thickness of the overcoat layer on the black matrix to 1 μm or less in order to obtain good viewing angle characteristics represented by a horizontal viewing angle of 110 degrees or greater (the performance of the phase difference compensation plate) without reducing the aperture ratio from 45 to 50 %.

[0032]

However, unless steps ranging from 1 to 2 μm on the black matrix are planarized, the directors of the liquid crystal are disturbed, causing an orientation failure. In view of this, the overcoat layer needs to be thin and the black matrix needs to be planarized by reducing maximum steps to 0.5 μm or less. Experimentation conducted by the inventor has shown that steps of the black matrix can be planarized and the thickness of the overcoat layer on the black matrix can be reduced to 1 μm or less by spin-coating an acrylic resin (PC405, PC415 manufactured by JSR) having a viscosity in the range from 5 to 15 mPa·s (5 to 15 cP) at the time of coating, as the overcoat layer.

[0033]

In the present embodiment, the description has been made for a case in which a black matrix is newly deposited on the color layers. However, adjacent color layers may be arranged in overlapping relation to provide a function equivalent to a black matrix.

[0034]

[Table 2]

Overcoat layer thickness d_{OC}	Overlapping region width W	Viewing angle 2θ	Aperture ratio
2 μm	2 μm	85 degrees	50 %
	3 μm	90 degrees	45 %
	4 μm	100 degrees	40 %
1 μm	2 μm	100 degrees	50 %
	3 μm	110 degrees	45 %
	4 μm	120 degrees	40 %
0.5 μm	2 μm	110 degrees	50 %
	3 μm	120 degrees	45 %
	4 μm	120 degrees	40 %

[0035]

FIG. 2 is a cross-sectional view showing the constitution of an active matrix liquid crystal display device according to a second embodiment of the present invention. This liquid crystal display device is similar to, but differs from, the liquid crystal display device shown in FIG. 1 in that black matrix 16 is disposed on the surface of the overcoat layer 14 closer to liquid crystal layer 30, but not on the surface of the overcoat layer 14 closer to data lines 12. In the present embodiment, black matrix 16 is disposed above data lines 12. Pixel electrodes 15 have edges covering black matrix 16. Since black matrix 16 is held in contact with a plurality of pixel electrodes 15, black matrix 16 needs to be made of an electrically insulating material. If black matrix 16 is made of a material having a high dielectric constant, then it can lessen the lateral electric field between pixel electrodes 15 in liquid crystal layer 30 and it can obtain the advantages that the width of light leakage region A is reduced.

[0036]

As with the case shown in FIG. 1, with this liquid crystal display device, the width of black matrix 16 may be determined depending on how large an angular range of light applied in an oblique direction and passing through only the light leakage region may be. Specifically, the position of the light leakage region is determined based on the thickness d_{LC} of liquid crystal layer 30, electrical properties of liquid crystal layer 30, spaced intervals and layout of pixel electrodes 15, and optical properties such as refractive indexes of the

various layers, and the width of black matrix 16 may be determined to obtain a desired viewing angle. According to a simpler process of determining the width of black matrix 16, which has been found by the present inventor, the thickness of the pixel electrodes is ignored, and the width W of the overlapping regions of pixel electrodes 15 and black matrix 16 is determined to meet the following condition:

$W \geq d_{LC}/2$ (for a case of the dot inversion driving process); and

$W \geq d_{LC}/4$ (for a case of the gate line inversion driving process).

[0037]

In this liquid crystal display device, the width W can be smaller than the width W in the liquid crystal display device shown in FIG. 1, and the aperture ratio of this device can be larger than the aperture ratio in the liquid crystal display device shown in FIG. 1.

[0038]

FIG. 3 is a cross-sectional view showing the constitution of an active matrix liquid crystal display device according to a third embodiment of the present invention. This liquid crystal display device is similar to, but differs from, the liquid crystal display device shown in FIG. 2 in that black matrix 16 disposed on overcoat layer 14 extends over edges of pixel electrodes 15.

[0039]

With this active matrix liquid crystal display device, as with the liquid crystal display device shown in FIG. 1, the width of black matrix 16 may be determined depending on how large an angular range of light applied in an oblique direction and passing through only the light leakage region may be. Specifically, the position of the light leakage region is determined based on the thickness d_{LC} of liquid crystal layer 30, electrical properties of liquid crystal layer 30, spaced intervals and layout of pixel electrodes 15, and optical properties such as refractive indexes of the various layers, and the width of black matrix 16 may be determined to obtain a desired viewing angle. According to a simpler process of determining the width of black matrix 16, which has been found by the present inventor, the thickness of the pixel electrodes is ignored, and the width W of the overlapping regions of pixel electrodes 15 and black

matrix 16 is determined to meet the following condition:

$W \geq d_{LC}/2$ (for a case of the dot inversion driving process); and

$W \geq d_{LC}/4$ (for a case of the gate line inversion driving process).

In this liquid crystal display device, the width W can further be reduced, and the aperture ratio can further be increased.

[0040]

FIG. 4 is a cross-section view showing the constitution of an active matrix liquid crystal display device according to a fourth embodiment of the present invention. This liquid crystal display device has the constitution that the overcoat layer s removed from the liquid crystal display device shown in FIG. 1. Pixel electrodes 15 are disposed directly on color layers 13, and have edges covering black matrix 16. Black matrix 16 is made of an electrically insulating material having a high dielectric constant.

[0041]

An overcoat layer would be used to lessen the lateral electric field applied to liquid crystal layer 30. If black matrix 16 is made of a material having a high dielectric constant, then black matrix 16 itself is effective to lessen the lateral electric field between pixel electrodes 15 in liquid crystal layer 30, make it possible to dispense with such an overcoat layer.

[0041]

With this liquid crystal display device, as with the liquid crystal display device shown in FIG. 1, the width of black matrix 16 may be determined depending on how large an angular range of light applied in an oblique direction and passing through only the light leakage region may be. Specifically, the position of the light leakage region is determined based on the thickness d_{LC} of liquid crystal layer 30, electrical properties of liquid crystal layer 30, spaced intervals and layout of pixel electrodes 15, and optical properties such as refractive indexes of the various layers, and the width of black matrix 16 may be determined to obtain a desired viewing angle. According to a simpler process of determining the width of black matrix 16, which has been found by the present inventor, the width W of the overlapping regions of pixel electrodes 15 and black matrix 16 is determined to meet the following condition:

$W \geq d_{LC}/2$ (for a case of the dot inversion driving process); and

$W \geq d_{LC}/4$ (for a case of the gate line inversion driving process).

[0042]

In this liquid crystal display device, inasmuch no overcoat layer is provided, the width W can be smaller than the width W in the liquid crystal display device shown in FIG. 1, and the aperture ratio can be increased.

[0043]

[Effect of the Invention]

According to the present invention, as described above, since the black matrix (a light shielding layer) is disposed on the TFT substrate, it is possible to increase the viewing angle without widening the data lines even if the color filters are disposed on the TFT substrate.

[Brief Description of the Drawings]

[FIG. 1]

FIG. 1 is a schematic cross-sectional view of an active matrix liquid crystal display device according to a first embodiment of the present invention.

[FIG. 2]

FIG. 2 is a schematic cross-sectional view of an active matrix liquid crystal display device according to a second embodiment of the present invention.

[FIG. 3]

FIG. 3 is a schematic cross-sectional view of an active matrix liquid crystal display device according to a third embodiment of the present invention.

[FIG. 4]

FIG. 4 is a schematic cross-sectional view of an active matrix liquid crystal display device according to a fourth embodiment of the present invention.

[FIG. 5]

FIG. 5 is a schematic cross-sectional view of a conventional active matrix liquid crystal display device.

[FIG. 6]

FIG. 6 is an equivalent circuit diagram of an active matrix liquid crystal display device.

[Explanation of Reference Numerals]

10	TFT substrate
11, 21	Glass substrate
12	Data line (Video signal line)
13	Color layer (Color filter)
14	Overcoat layer
15	Pixel electrode
16	Black matrix (Light shielding layer)
20	Opposing substrate
21	Glass substrate
22	Common electrode
30	Liquid crystal layer
31	Director
40	Pixel portion
41	TFT
42	Gate line (Scanning line)
43	Pixel capacitor
44, 45	Driver
A	Light leakage region

[Document Name] Abstract

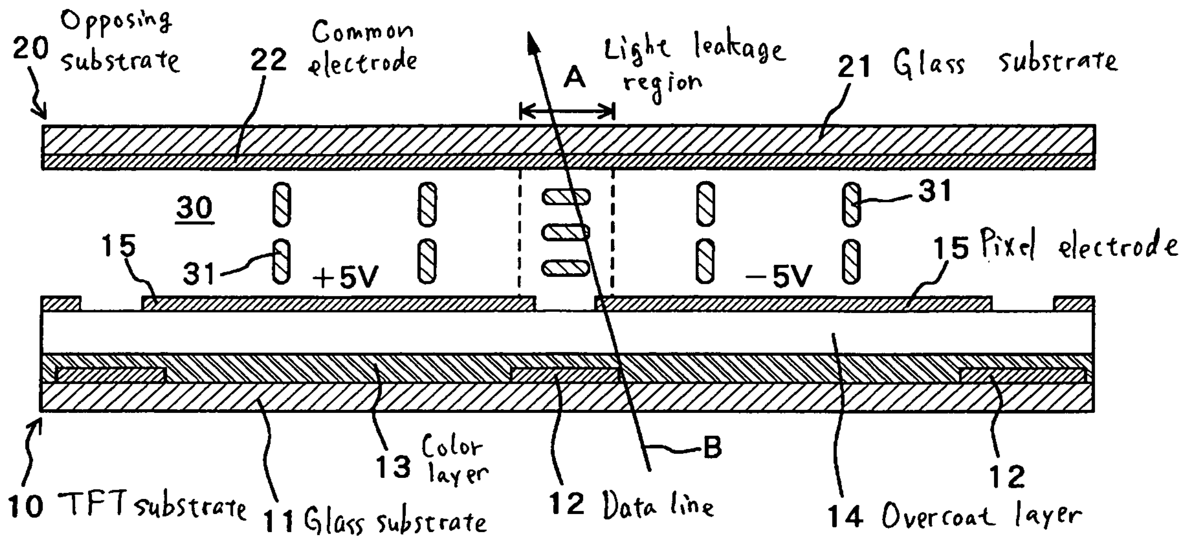
[Abstract]

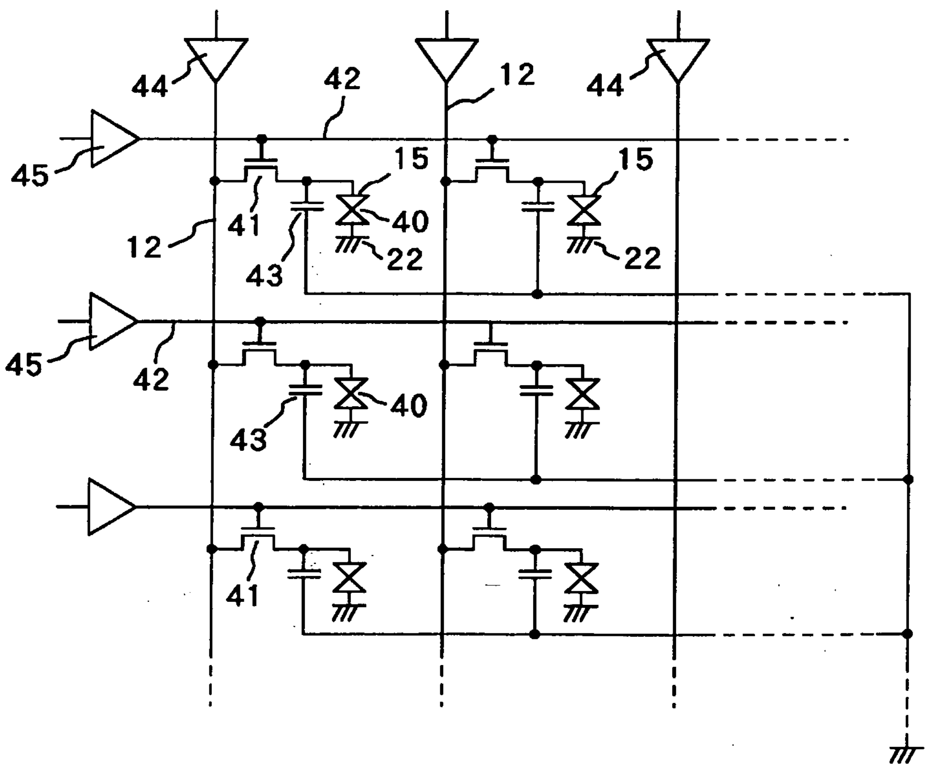
[Problem to be Solved] To reduce affection by a light leakage region generated on a data line to widen a viewing angle in active matrix liquid crystal display device even if a color filter is disposed on a TFT substrate side.

[Solution] Between data line 12 and overcoat layer 16, black matrix 16 is inserted along data line 12. The dimension of black matrix 16 is determined such that black matrix 16 blocks the light (arrow A) passing in a predetermined viewing angle range through light leakage region A created in liquid crystal layer 30 depending on a potential difference between adjacent two of the pixel electrodes 15.

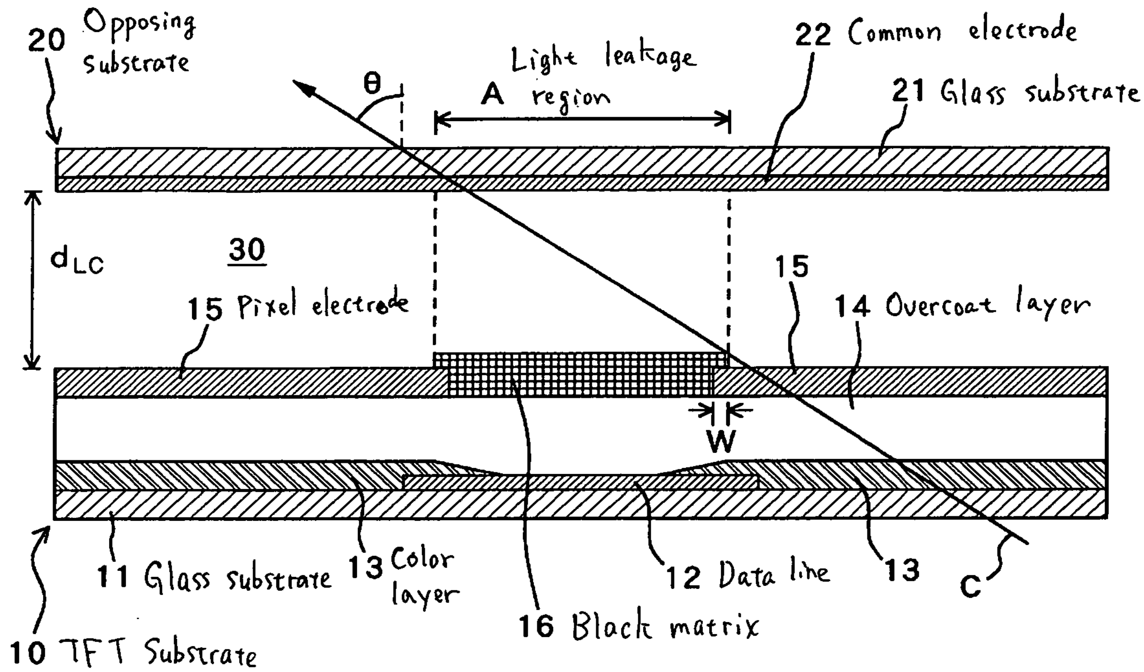
[Representative drawing] FIG. 1

[FIG.5]


20
Opposing substrate
22
Common electrode
A
Light leakage region
21 Glass substrate
30
31
15
31
+5V
-5V
15 Pixel electrode
B
10 TFT substrate
11 Glass substrate
13 Color layer
12 Data line
14 Overcoat layer
12

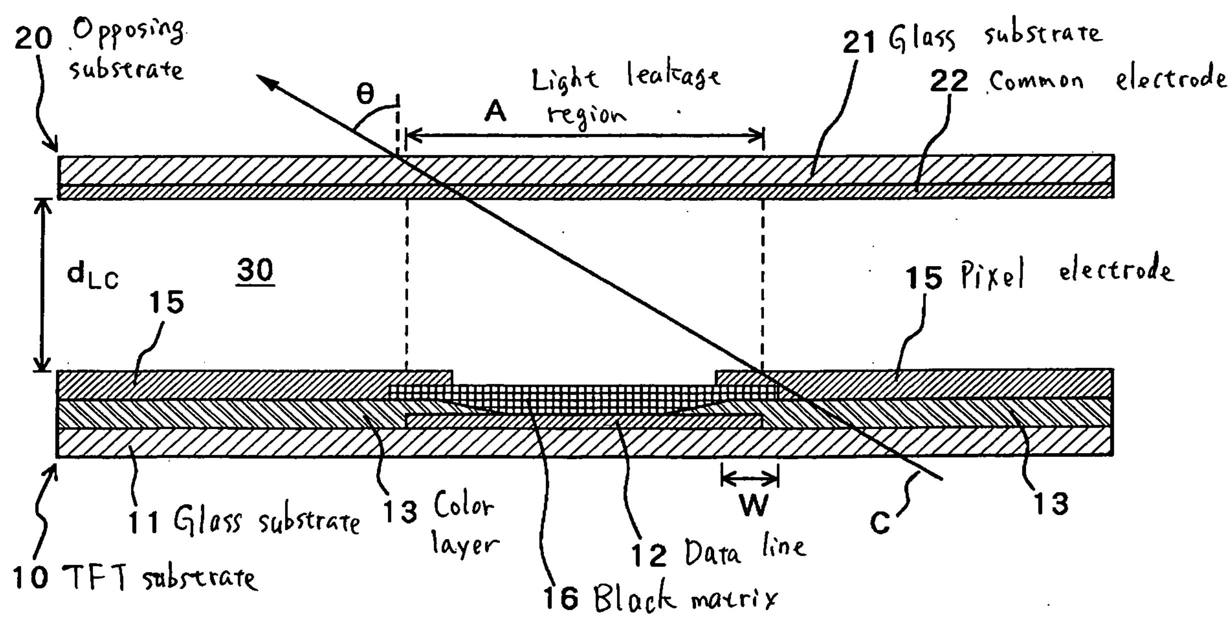

44
42
12
44
45
15
15
41
40
12
43
22
22
45
42
40
43
41

[FIG. 3]



20 Opposing substrate
θ
Light leakage
A region
22 Common electrode
21 Glass substrate
d_{LC}
30
15
15 Pixel electrode
14 Overcoat layer
W
11 Glass substrate
13 Color layer
12 Data line
13
C
16 Black matrix
10 TFT Substrate

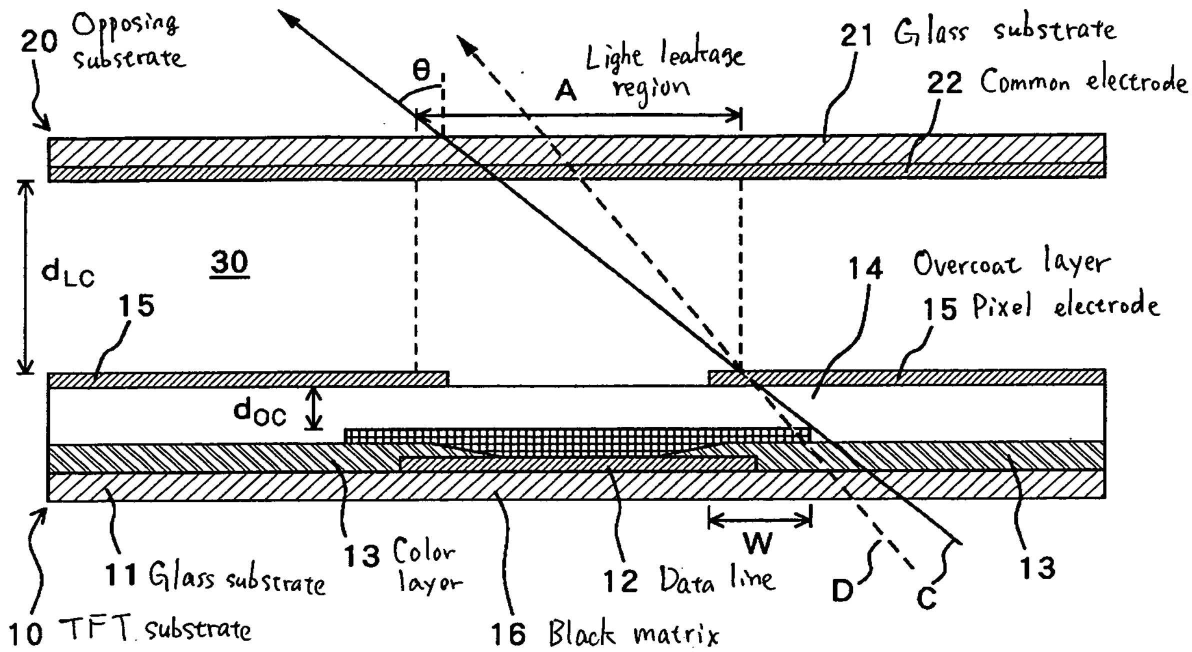
[FIG. 4]



20 Opposing substrate
θ
Light leakage
A region
21 Glass substrate
22 Common electrode
d_{LC}
30
15
15 Pixel electrode
W
11 Glass substrate
13 Color layer
12 Data line
C
13
10 TFT substrate
16 Black matrix

[Document Name] Drawings

[FIG. 1]



[FIG. 2]